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RESEARCH ARTICLE

REDUCING THERMAL INERTIA TO IMPROVE THERMAL COMFORT BY CONFIGURATION OF A NEW BRICK

Louis Okotaka Ebale, Narcisse Malanda, Loubouth Severin Jean Maixent and Doria Vaneça Ngambomi
Laboratoire de Mécanique, Energétique et Ingénierie, Ecole Nationale Supérieure Polytechnique, Université Marien Ngouabi, Berazzaville, Congo.

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Abstract

Climate change has changed seasons, affecting the indoor temperature of buildings and causing a strong feeling of discomfort, especially in hot weather. This feeling of discomfort is mainly due to thermal inertia. The aim of this work is to reduce the indoor temperature of buildings by using a new brick with a low thermal inertia. As part of this work we have designed a brick with the same characteristics as the ordinary ones but which are perforated so that in the construction of the wall they form a conduit for the transport of air. The latter thus acts as a heat transfer fluid in its upward convective movement, bringing with it the heat stored in the wall. In order to improve thermal exchange, an air-extractor roller system has been installed. This air extractor allows to increase convection in the walls, reducing thermal inertia and implicitly improving thermal comfort.

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Introduction:-

The building is a structure that protects its occupants from the bad weather and provides a pleasant interior setting, regardless of the outside conditions (weather and acoustics). For this reason, a good design of the building is essential to ensure comfort through the judicious use of technical, architectural and constructional devices, providing the appropriate thermal conditions (such as the type of solar protectors, reasonable thermal inertia, orientation, natural ventilation and low electrical internal load) [1]. Currently, thermal comfort is a concern in buildings because of its impact on indoor environment quality, health and occupant productivity. This concern is supported by standards and regulations that ensure that the interior environment complies with the requirements of thermal comfort [2]. On the other hand, several elements have an influence on the interior atmosphere of the buildings. These include: thermal inertia [3, 4]. This inertia is usually caused by thick walls, the use of masonry slabs, and/or slit walls and many others [5,6]. In fact, there is a phase-out between the moment when sunlight hits the outer walls and the moment when heat is evacuated by the wall inside the building. In other words, the heat is stored in the wall while it is hot outside the building and is later re-circulated to the building when the outside temperature drops. In order to overcome this phase, it is necessary that the inertia of the construction be as low as possible [7, 8, 9]. Although the comfort of a building depends on its architecture, it also depends on the quality of the materials used for its construction (materials used to make floors, vertical walls or roof). The environment outside Congo is characterized by a humid tropical climate and has mainly two seasons: the rainy season and the dry season. In general, it is hot in the rainy season and cool in the dry season [10]. The feeling of discomfort inside the buildings is much more felt by the occupants during the rainy season. In this study, our focus will be solely on thermal comfort in the rainy season, precisely by improving the temperature inside buildings in hot weather [11,12]. Specialty documents stipulate that the comfort temperature in the tropical zone varies between 20°C and 27°C. Also,

Corresponding Author:- Louis Okotaka Ebale

Address:- Laboratoire de Mécanique, Energétique et Ingénierie, Ecole Nationale Supérieure Polytechnique, Université Marien Ngouabi, Berazzaville, Congo.

ASHRAE 55-81 recommends ambient temperatures between 22°C and 26°C for the summer. Similarly, ISO 7730 (AFNOR 1995) recommends ambient temperatures between 23°C and 26°C, so that thermal comfort is guaranteed in the construction. However, with the phenomenon of climate change, the seasons are disrupted, thus affecting the interior temperature of the buildings and causing a strong feeling of discomfort to the occupants, especially in hot weather. The elements usually used for the construction of the walls during the construction of the buildings, do not really contribute to thermal comfort in hot time due to their high thermal inertia. In order to reduce this thermal inertia we have designed a new brick with the same characteristics as the brick used usually but with this time low thermal inertia [13-16]. They are perforated so that in the construction of the wall they form a conduit for the transport of air, **Figure 1**. This air then acts as a heat transfer fluid in an upward convective movement, driving the heat stored in the wall into the ducts, thus reducing the thermal inertia. Two buildings were built for this purpose, one of ordinary bricks and the other of new bricks. **Figure 2** and **3**. A permanent thermal balance of each room is achieved by considering a constant difference of 2°C between the interior and the exterior. The role of this body is to determine the relative amount of heat. As the indoor temperatures of the premises depend on the variation in the outdoor temperature, daily measurements are made simultaneously for each room between 9 a.m. and 9 p.m. They will demonstrate that the new configuration brick reduces heat intakes in buildings. The use of a flap system with air extractor. **Figure 4** and **5**, allows to intensify thermal convection in the ducts, thereby reducing thermal inertia in the building walls.

Material and Method:-

In Figure 1, the prototype of the building constructed with ordinary bricks is presented. Figure 2 shows the prototype of the building constructed with the new configuration brick. Figure 3 shows that orifices have been made on the walls to allow the evacuation of the hot air stored in the walls through the ducts made by the overlay of the bricks. Figure 4 shows the same building constructed this time with the new brick, equipped with a joint and an air extractor for the construction of a forced thermal convection Figure 5.



Figure 3:- Perforated bricks.

The characteristics of the prototype buildings

1. Volume of building: 1m³
2. Outdoor walls in hollow agglomerated without outer and inner coatings: 15 cm
3. Thickness floor: 10 cm
4. 4mm plywood ceiling, high ceiling: 1m
5. The size doors: 0,30 x 0,60m
6. The roof being on an unventilated top



Figure 1:- Building constructed with normal non-perforated conventional bricks.

Site Geographic Coordinates

According to the National Civil Aviation Agency (ANAC), the geographic coordinates of the city of Brazzaville are:

Altitude : 313 m;

Latitude : 4, 25°S ;

Longitude : 15,25°E ;



Figure 2:-Building built of perforated bricks and air circulation by natural convection

Basic climatic conditions of the site

The calculations were made at a time when the outside temperature is low and the walls of the room subjected to thermal inertia begin to release the accumulated heat. They will be based on temperature readings from 9 a.m. to 9 p.m. in November 2019.

Basic external conditions

1. Maximum daily outside temperature: 32°C
2. Minimum daily outside temperature: 26°C
3. Relative humidity: 55%

Domestic conditions

Inner temperature of the room made with ordinary bricks: 30°C

Indoor temperature made with new bricks: 30°C



Figure 4:- A building made of perforated bricks equipped with a shaft with air extractor



Figure 5:- Air extractor AP3102:80mm. 55m3/h. 23W.

Thermal balance of the space made of normal bricks

The thermal balance of the space made of normal bricks allows to determine the different thermal flows. We will consider a permanent regime with an estimated temperature deviation of 2°C and constant thermal exchange coefficients U_p and U_T .

Heat inputs from external walls $Q_{\Delta T}$ due to temperature difference with outside environment

This input is calculated by the fundamental expression of thermal transfer. It is proportional to the thermal exchange coefficients U_p and U_T , the surfaces of the building's wall S and the roof S_T . The expression of this heat is:

$$Q_{\Delta T} = (U_p S + U_T S_T) \Delta T [W] \quad (1)$$

$$S = S_{Nord} + S_{Sud} + S_{Est} + S_{Ouest} \quad (2)$$

Q_{SR} heat inputs through outer walls due to solar radiation

Solar intakes vary with the time of year, day and geographic location. To simplify the calculations, a fictitious temperature difference due to sunlight is introduced. This fictitious deviation is determined by an initial fictitious deviation of temperature, $\Delta T_{\text{initiale}}$:

$$Q_{SR} = (U_p S + U_T S_T) \Delta T_{fc} [W] \quad (3)$$

Determination of the initial and corrected variances of temperature final $\Delta T_{\text{initiale}}$ et ΔT_{fc} .

This initial fictitious temperature difference, $\Delta T_{\text{initiale}}$ was confirmed as final, will be determined for a latitude of 40° north or south and for the months of January and July. The calculation for any other months and latitude is made by correcting the values $\Delta T_{\text{initiale}}$ of the final referendum in order to obtain a corrected temperature difference ΔT_{fc} . The different parameters to consider for the correction of developerfinal $\Delta T_{\text{initiale}}$ are: The latitude and month of the year correction is obtained by using a F_e correction coefficient that corrects the temperature difference. The wall surface mass, which characterizes the thermal inertia of the walls, should also be taken into account. We consider our structure to be light, the mass is less than $< 75 \text{ kg/m}^2$. The color of the wall that receives the solar radiation causes a more or less large absorption of the solar radiation depending on the color of the walls. The difference in initial temperature $\Delta T_{\text{initiale}}$ was reduced by the factor $F_a = 0.55$ for light colored walls. The initial differences $\Delta T_{\text{initiale}}$ that were developed were experimentally obtained under the following conditions: $(T_{\text{ext}} - t_{\text{ext}}) = 11^\circ\text{C}$ and $(T_{\text{ext}} - T_{\text{int}}) = 8^\circ\text{C}$. When these conditions are not met, a correction must be made to the values of developfc by adding in our case the value $T_{\text{cor}} = -2.5^\circ\text{C}$ []. The relationship is as follows:

$$\Delta T_{fc} = \Delta T_{\text{initiale}} \times F_e \times F_a + T_{\text{cor}} [^\circ\text{C}] \quad (4)$$

The heat input from solar radiation is proportional to the heat exchange coefficients U_p and U_T , the surfaces of the S and S_T walls and the fictitious temperature deviation that was corrected, ΔT_{fc} .

Thermal balance of the space made of bricks of new configurations

The thermal balance of the space made of new bricks allows to determine the different thermal flows. We will consider a permanent regime with an estimated temperature deviation of 2°C and constant U_{bn} and U_T thermal exchange coefficients.[14-16]

Heat inputs $Q_{\Delta Tnb}$ due to the difference in temperature across walls constructed with bricks of new configuration

This input is calculated by the fundamental expression of thermal transfer. It is proportional to the heat exchange coefficient U_{bn} and U_T , the surfaces of the walls of building S , and the surface of roof S_T . The expression of this heat is:

$$Q_{\Delta Tnb} = (U_{nb}S + U_T S_T) \Delta T [W] \quad (5)$$

Determination of the thermal U_{nb} exchange coefficient of the new brick

The wall built with the new bricks involves a heat exchange by natural convection through a duct made by the overlay of the bricks. When the wall is heated outside by solar radiation, the temperature t_{p1} and the temperature T_{p2} appear between the outer walls, with $t_{p1} > t_{p2}$. The air in the ducts is subjected to upward convective motion. This natural convection is primarily studied using the additional quantities called Prandtl Number and Grashof Number. The thermal-physical dimensions of calculation are shown in **Table 1**.

The Number of Prandtl.

The number of Prandtl contains the thermal-physical properties of the fluid, in our case it is air.

$$Pr = \frac{c\mu}{\lambda} \quad (6)$$

The Number of Grashof

The Number of Grashof characterizes the natural flow of fluid in the vicinity of the wall surface due to the difference in temperature.

$$Gr = \frac{l^3 \rho^2 g \beta \Delta \theta}{\mu^2} \quad (7)$$

Table 1:-Thermo-physical characteristics of heat exchange

t_m [°C]	c [$\frac{kJ}{kg^\circ C}$]	μ [$\frac{Ns}{m^2}$]	λ [$\frac{W}{m^\circ C}$]	ρ [$\frac{kg}{m^3}$]	β [$^\circ C^{-1}$]	g [$\frac{m}{s^2}$]	$\Delta \theta$ [°C]
31	1,007	$9,3279 \cdot 10^{-4}$	0,0266	1,1476	0,03226	9,81	2

The thermal flux through a layer of bulk fluid (m) delimited by temperature walls t_{p1} and t_{p2} can be calculated by the thermal conduction relationship in the form:

$$q_s = U_{nb} (t_{p1} - t_{p2}) = \frac{\lambda_{ech}}{\delta} (t_{p1} - t_{p2}) \left[\frac{W}{m^2} \right] \quad (8)$$

This expression allows us to calculate the heat exchange coefficient by the relationship:

$$U_{nb} = \frac{\lambda_{ech}}{\delta} \left[\frac{W}{m^2^\circ C} \right] \quad (9)$$

The equivalent conductivity of fluid λ_{ech} is determined by the relationship:

$$\lambda_{ech} = \lambda \varepsilon_c \quad (10)$$

In which ε_c is the incremental coefficient of the influence of thermal convection. It is calculated by the relationship [14]:

$$\varepsilon_C = 0,18(G_{rm}P_{rm})^{0,25} \quad (11)$$

This relationship is only valid if the product ($G_{rm}P_{rm}$) is in the interval:

$$10^3 < G_{rm}P_{rm} < 10^{10} \quad (12)$$

The values of G_{rm} and P_{rm} are calculated by taking the mean temperature t_m :

$$t_m = \frac{t_{p1} + t_{p2}}{2} \quad (13)$$

Heat inputs Q_{SRnb} due to solar radiation through walls constructed with new configuration bricks

The heat input from Q_{SRnb} solar radiation is proportional to the thermal exchange coefficients of the roof and walls constructed by the new U_{nb} , brick, the S and S_T surfaces, and the fictitious temperature deviation corrected $\Delta T_{fc}(3)$. It is calculated by the relationship:

$$Q_{SRnb} = (U_{np}S + U_T S_T) \Delta T_{fc} [W] \quad (14)$$

The factors required to determine whether or not it is necessary to determine whether or not it is necessary to determine whether or not it is necessary to do so.

Results And Discussion:-

In order to compare the heat intakes of the two premises, we have made a thermal balance of the different heat flows through each wall [11,13]. Initially, we considered the heat intakes due to temperature differences in normal brick walls for a permanent regime with a constant temperature difference estimated at 2°C **Tables 2, 6**.

Table 2:- Heat input $Q_{\Delta T}$ due to the temperature gap in the wall made of normal brick.

Orientation des Parois	Surface $[m^2]$	Coefficient U $\left[\frac{W}{m^2 \cdot ^\circ C}\right]$	ΔT $[^\circ C]$	$Q_{\Delta T}$ $[W]$
Nord	1	1,86	2	3,72
Sud	0,82	1,86	2	3,05
Ouest	1	1,86	2	3,72
Est	1	1,86	2	3,72
Porte	0,18	1	2	0,36
Toiture	1,99	0,34	2	1,35
TOTAL				15,92

To take solar radiation into account, the correction factors (3) were used in relation (2). **Table 3,4,7** presents the results of the calculations. In a second step, we considered the heat intakes due to temperature differences through the walls constructed with bricks of new configuration for a permanent regime with a constant temperature deviation estimated at 2°C.

Table 3:- Corrected Fictitious Temperature Variance ΔT_{fc}

Orientation des Parois	$\Delta T_{initiale}$ $[^\circ C]$	F_e	F_a	T_c $[^\circ C]$	ΔT_{fc} $[^\circ C]$
Nord	17,5°C	0,36	0,55	-2,5	0,965
Sud	9°C	4	0,55	-2,5	17,3
Ouest	19°C	0,91	0,55	-2,5	9,5
Est	10,5°C	0,91	0,55	-2,5	2,7
Toiture	25°C	1,05	0,55	-2,5	11,94

The configuration of the new brick required the calculation of a new thermal exchange coefficient [14-16]. The quantities used for the calculation were presented in **Table 5**. To take solar radiation into account, we used the same correction factors as for normal bricks. **Table 4** presents the results of these calculations.

Table 4:- $Q_{\Delta SR}$ heat input due to solar radiation from the normal brick wall.

Orientation des Parois	Surface [m ²]	Coefficient U $\left[\frac{W}{m^2 \cdot ^\circ C}\right]$	ΔT_{fc} [°C]	$Q_{\Delta SR}$ [W]
Nord	1	1,86	0,965	1,795
Sud	0,82	1,86	17,3	26,39
Ouest	1	1,86	9,5	17,67
Est	1	1,86	2,7	5,02
Toiture	1,99	0,34	11,94	8,09
TOTAL				58,97

The results of **Table 8** clearly show that the space constructed with the bricks of the new configuration accumulates very little heat and therefore has low thermal inertia. Most of the heat is transported by air in natural convection through the ducts made up of bricks.

Table 5:- Calculation of heat exchange coefficient

P_{rm}	G_{rm}	ε_c	λ_{ech} $\left[\frac{W}{m \cdot ^\circ C}\right]$	δ [m]	U_{nb} $\left[\frac{W}{m^2 \cdot ^\circ C}\right]$
0,035	30656,79	1,03	0,0274	0,09	0,30

Table 6:- Heat input $Q_{\Delta Tnb}$ due to the difference in wall temperature made of new bricks

Orientation des Parois	Surface [m ²]	Coefficient U $\left[\frac{W}{m^2 \cdot ^\circ C}\right]$	ΔT [°C]	$Q_{\Delta Tnb}$ [W]
Nord	1	0,30	2	0,6
Sud	0,82	0,30	2	0,492
Ouest	1	0,30	2	0,6
Est	1	0,30	2	0,6
Porte	0,18	1	2	0,36
Toiture	1,99	0,34	2	1, 35

We also know that the evacuation of this heat is much higher when convection is forced. For example, the installation of a flap and an air extractor fan was recommended in order to increase heat exchange.

Table 7:- Heat input Q_{SRnb} due to solar radiation from the wall made of new bricks

Orientation des Parois	Surface [m ²]	Coefficient U $\left[\frac{W}{m^2 \cdot ^\circ C}\right]$	ΔT_c [°C]	Q_{SRnb} [W]
Nord	1	0,30	0,965	0,2895
Sud	0,82	0,30	17,3	4,3
Ouest	1	0,30	9,5	2,85

Est	1	0,30	2,7	3,582
Toiture	1,99	0,34	11,94	8,09
TOTAL				19,11

The results obtained and presented in **Table 8** were realized on the assumption that the regime was permanent, i.e. independent of time, in reality the regime is not permanent, the regime is dynamic, the variation of the interior temperature of each room is dependent on external climatic variations [12,13,14]. Figure 6 shows several curves of variation in temperature of the different spaces according to the outside temperature.

Table 8:- Summary of Heat Intakes of the Two Walls.

Local	Chaleur due à la différence de température [W]	Chaleur due au rayonnement solaire [W]	Chaleur totale [W]
brique normal	15,92	58,97	74,89
brique nouvelle	4,002	19,11	23,11

In **Figure 6**, the maximum outside temperature curve is 13 hours, 35°C. At the same time, the temperature of the room built with ordinary bricks is also 35°C. On the other hand, the temperature of the room built with the bricks of new configurations is just below with a temperature of 34°C.

While the temperature of the room equipped with a flap and an air extractor is 32°C. The new brick accumulates less heat than the ordinary brick.

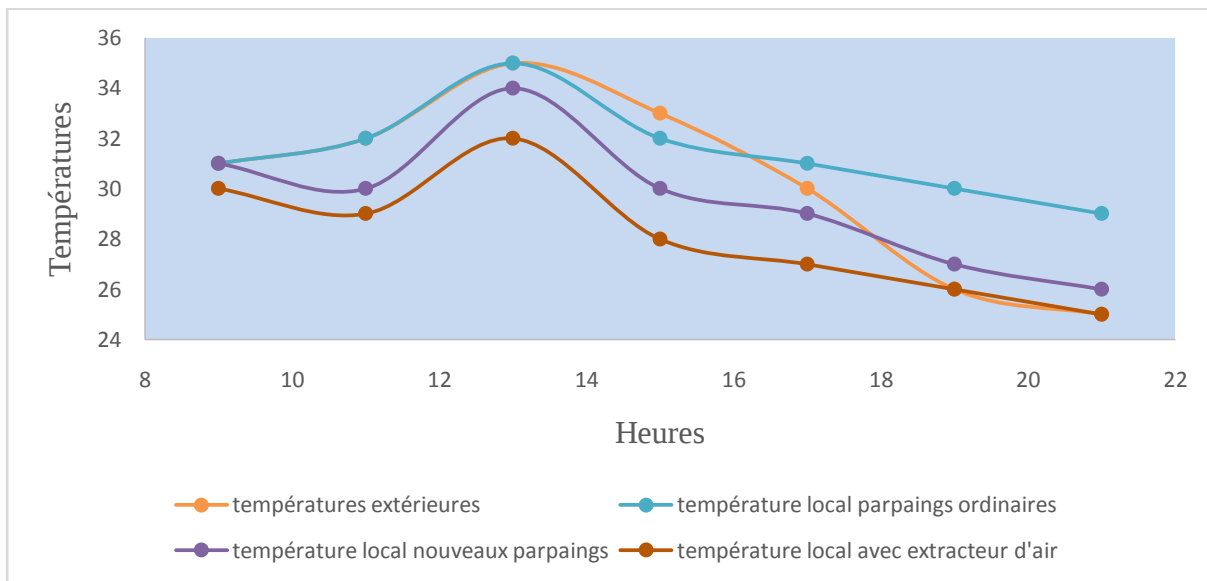


Figure 6:- Temperature curves change over time.

From 1 p.m. the curve of the outside temperature begins a slope down to a temperature of 25°C at about 21 hours. At the same time the temperature curve of the room with the ordinary brick slowly descends to the temperature of 30°C by 21 hours and at the same time, the temperature curve of the room built with the bricks of new configurations arrives around 21 hours at 27°C. The room with air extractor joins the temperature curve of the outdoor environment at 25°C. Figure 6 shows that there is a gap between the temperature curve of the room constructed with ordinary bricks and the temperature curve of the room constructed with new bricks from 13 hours to 21 hours. This difference is even greater when the room has an air-extracting fan shaft system. The heat that was to accumulate in the walls is extracted through the ducts by the fan, substantially reducing the thermal inertia.

Conclusion:-

The aim of this work was to tackle the problem of global warming and limit these consequences in buildings. It was built for this purpose, two premises, one with ordinary bricks and the other with new bricks. The wall of the room made with the new configuration brick has holes that allow the outside air to flow down and then outward upward. This one actually plays a role as a heat transfer fluid that causes some of the heat flow with it. The first experience of air transport was in natural convection. The results give a temperature difference between 1°C and 2°C, when the outside temperature drops. The second experiment in air transport was forced convection. The results give a temperature difference between 2°C and 3°C between the two premises. The calculation of the thermal balance of the two premises shows how the space made with the new brick configuration emits less heat than the space made with ordinary bricks. The analysis of temperature readings confirms that the new brick has less thermal inertia than the ordinary brick. Compared to the temperature readings that we may have had in forced convection, the temperatures in the room made with the new bricks are quite close to those prescribed by ASHRAE 55-81, ISO 7730 (AFNOR 1995).

This way, we can say that the new parping configuration plays a dual role because it reduces the thermal inertia in a building and helps to reduce overheating during the hottest times of the day and even in the evening when the outside temperature drops. The next step in enhancing our results will be to: to study the resistance of the experimental brick to determine if it meets the requirements of the standards and to perform a simulation to see how the heat flow moves in the wall of the two spaces. From the results of the simulation, it will be possible to improve the performance of our new brick. This simulation can be done either with the analytical method, with the numerical method (finite elements, finite differences) or with both methods, and finally a comparison of the results of the two methods.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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